Last week, I introduced what I call “first generation” genetically modified organisms (GMOs) – altered bacteria for diverse, mostly indoor purposes – and “second generation” ones – GM crops and agricultural animals. Here, I describe third generation GMOs, which are those that would be intentionally placed into natural environments, where they would live, reproduce, and transmit their modified genes to offspring. These GMOs can be created through either older, transgenic methods that transfer genes from another species or newer CRISPR-based methods that more precisely edit genes.

Oxitec GM mosquitoes are released in the Cayman Islands. Photo by Taneos Ramsay of the Cayman Compass.

A few potential uses can clarify. Some applications would aim to improve human well-being, particularly by combating disease vectors. Mosquitoes are arguably the world’s deadliest animal through their transmission of numerous diseases, most importantly malaria. Some of a mosquito population (that is, those organisms within a given local ecological community) could be genetically modified to not transmit the disease, to not bite humans, or to locally reduce their numbers. For example, the UK company Oxitec has developed male GM mosquitoes whose female offspring – which are the only ones that bite – do not survive to adulthood and whose male offspring propagate this genetic infertility when they mate with non-modified females. Over time, the local population shrinks in size due to a lack of females. Oxitec has tested its GM mosquitoes outdoors in Brazil, Panama, and the Cayman Islands, and the company wishes to do so in Texas and the Florida Keys. Similarly, MIT researchers are consulting with residents of Martha’s Vineyard and Nantucket, islands off the Massachusetts coast, regarding the possible release of GM mice that would not transmit Lyme disease. In both cases, some environmental advocates oppose these releases, which

regulators would need to approve. For example, the US Environmental Protection Agency considers Oxitec's GM mosquitoes to be pesticides, requiring an experimental use permit.

Third generation GMOs could be used also for sustainability objectives, including the conservation of biodiversity. One simple application would be to genetically label some organisms with an identifiable genetic "bar code" to track their movements, population dynamics, and gene flow. Another would be to eradicate invasive alien species, which are one of the leading drivers of biodiversity loss. For example, a foreign mosquito in Hawaii has introduced and is spreading avian malaria there, threatening the honeycreeper (a bird). These mosquito populations could be modified or suppressed by the techniques described above.

Perhaps more interesting is the prospect of genetically modifying species to help them adapt to changing conditions. An invasive fungal disease appears to be the leading cause behind recent declines in amphibian populations, while marine corals suffer from a double onslaught of warming and acidifying water caused by anthropogenic carbon dioxide emissions. These species could – at least in principle – be genetically modified to resist the disease or to thrive in the new conditions. Furthermore, nearly or perhaps fully extinct species could be revived. The American chestnut tree dominated eastern forests through the late 19th century, but an invasive fungal blight destroyed them, with survivors only in human-created forests in the western US. After thirty years of efforts, scientists at the State University of New York have developed a GM chestnut and asked the three relevant federal regulatory bodies for approval. The Revive and Restore organization is more ambitious, using a mix of tools – selective breeding, cloning, genetic modification, and ecosystem restoration – to bring back a handful of nearly and truly extinct species. (Yes, this includes the woolly mammoth.)

These ecocentric applications raise normative and legal questions quite different from previous GMOs, which were mainly for humans' benefit. Biotechnology has often been presented as a threat to biodiversity, yet some of these third generation GMOs could help conserve biodiversity, presenting a tension in governance. Environmentalists appear split on these issues, with some supporting GMOs for conservation, some opposing, and most quiet.

In my next posts, I will describe fourth generation GMOs and global governance thereafter.